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Audit of the Vulcanus Incineration Ship Prior to the August 1982 PCB Burn Mobile, Alabama

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Prepared for

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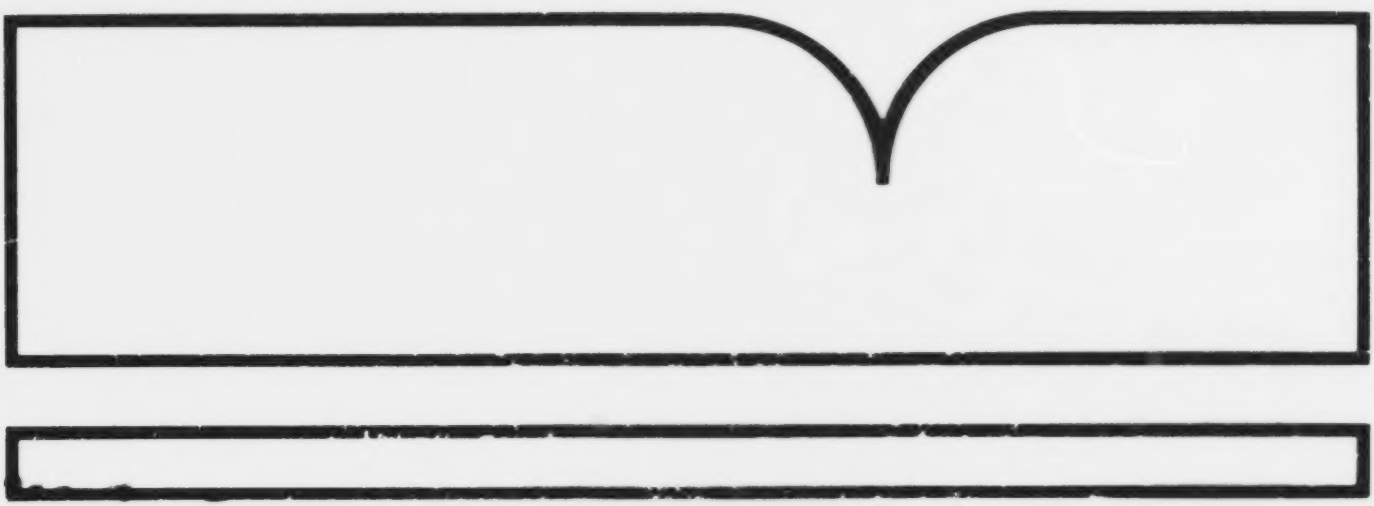

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AUDIT OF THE VULCANUS INCINERATION SHIP PRIOR TO THE AUGUST 1982 PCB BURN MOBILE, ALABAMA

by

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16. ABSTRACT The report gives results of an evaluation of three systems aboard the Vulcanus, a Singapore-registered tanker that has been converted for incinerating industrial waste at sea. The ship has been operating for several years, disposing of various chemical wastes generated mainly in the European community. Industrial waste disposal by incineration at sea is also an option for U.S. waste management systems and thus is of interest to the EPA. In August 1982, the EPA had an opportunity to study, at sea, the incineration (by the Vulcanus) of transformer oil containing polychlorinated biphenyls. Because of the special interest in this project, the quality assurance officer of the EPA's Industrial Environmental Research Laboratory at Research Triangle Park (IERL-RTP) directed Research Triangle Institute (RTI) to conduct an independent evaluation of the ship's continuous emission monitoring system, incinerator temperature measurement system, and the TRW sampling train prior to the test burn. The RTI audit team performed this evaluation August 11-13, 1982, while the Vulcanus was docked at Chickasaw Harbor near Mobile, Alabama. Audit results include a summary of audit results, audit procedures, audit calculations, test results, recommendations, and audit standards.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Chlorine Aromatic Compounds	Monitors	At-sea Incineration		
Biphenyl	Measurement	Polychlorinated Biphenyls	07C	
Liquids	Sampling			14B
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ABSTRACT

Systems and performance audits were conducted of instrumentation aboard the incinerator ship MT VULCANUS August 12-13, 1982. Instrumentation audited included the continuous emission monitoring system (CEMS) which measured the concentrations of oxygen (O_2), carbon monoxide (CO), and carbon dioxide (CO_2) in the incinerator effluent. Also audited were four thermocouples (which measured incinerator wall temperatures) and a Method 5 sampling system (operated by TRW, Inc.).

The audit disclosed that the CO monitor produced measurements which were 35.4 percent lower than expected; performance of the O_2 and CO_2 monitors was satisfactory. A leak, detected by the auditors in the starboard incinerator sampling system, was corrected by the ship's personnel. The combustion thermocouple readout meters performed satisfactorily; however, the portside Plastomatic thermocouple readout meter averaged 7.2 percent less than expected, and the starboard Plastomatic thermocouple readout meter averaged 15.7 percent greater than expected. Results of the Method 5 dry gas meter audit originally indicated that TRW's meter was 11 percent less than expected. Recalculations by TRW reduced the differences to less than 3 percent.

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SECTION 1

INTRODUCTION

The Vulcanus is a Singapore registered tanker which has been converted for incinerating industrial waste at sea. This ship has been operating for several years disposing of various chemical wastes generated mainly in the European community. Industrial waste disposal by incineration at sea is also an option for American waste management systems and thus is of interest to the U.S. Environmental Protection Agency (EPA).

In August of 1982, the EPA had an opportunity to study at sea, the incineration of transformer oil containing polychlorinated biphenyls (PCB) by the Vulcanus. Mr. Merrill Jackson, head of the EPA investigative team, was assisted in this task by others from EPA and by TRW contract personnel experienced in such source testing and fugitive emission evaluation.

Because of the special interest of this project, the quality assurance officer for EPA's Industrial Environmental Research Laboratory (IERL) directed the Research Triangle Institute (RTI) to conduct an independant evaluation of the ship's continuous emission monitoring system, incinerator temperature measurement system, and the TRW sampling train prior to the test burn. The RTI audit team performed this evaluation between August 11 and August 13, 1982, while the Vulcanus was docked at Chickasaw Harbor near Mobile, Alabama.

The results of the RTI audit are presented in the following sections. Section 2 contains a summary of audit results; Section 3 describes the audit procedures; Section 4 presents the audit calculations; Section 5 contains the results of testing; Section 6 presents recommendations; and Section 7 describes the audit standards.

SECTION 2

SUMMARY

2.1 CONTINUOUS EMISSION MONITORING SYSTEM AUDIT

The continuous emission monitoring system (CEMS) was audited by supplying known concentrations of the pollutants of interest directly to the CEMS's ceramic probe located inside the incinerator. A summary of the results are presented in Table 1. Examination of the results show only the CO analyzer to be producing unsatisfactory data. Also of note is the positive intercept for the O_2 analyzer. This analyzer produced positive readings while sampling the audit cylinder containing nitrogen only. Examination of the starboard sampling system disclosed a leak between the Teflon sample line and the incinerator wall mounting device. The leak was subsequently corrected. No such leak was detected in the port side sampling system.

TABLE 1. SUMMARY OF THE CONTINUOUS EMISSION MONITORING SYSTEM'S AUDIT RESULTS

Monitor S/N	Parameter	Average Difference		Regression of monitor response (Y) on audit conc. (X); Y = mX + b		
		(PPM)	(%)[a]	Slope (m)	Intercept (b)	Corr. Coeff. (r)
M04-478	O_2	3,900	7.6	0.883	0.74[c]	0.9997
M03-949	CO_2	6,200	8.5	1.025	0.34	0.9969
M04-54	CO	-38.7	-35.4	0.750	-6.6	0.9938

[a] Values reported are the averages of the percent differences calculated as follows:

$$\frac{\text{Analyzer Response - Audit Conc.}}{\text{Audit Conc.}} \times 100 = \text{Percent Difference}$$

[c] A leak in the starboard sampling system was identified and corrected.

2.2 TEMPERATURE MEASUREMENT SYSTEM AUDIT

The temperature of the incinerator wall is monitored by a temperature measurement system consisting of thermocouples and readout meters. An audit of the meters was conducted by delivering known millivolt currents to the meters. Results of the audit are presented in Table 2. The results show the starboard plastomatic thermocouple readout meter located in the camerabox read 15.7 percent higher on the average than the input voltages. The calculated error at a simulated temperature of 1200°C would be 9.7 percent for this meter. Similarly, the portside plastomatic thermocouple readout meter read 7.2 percent lower on the average than the input voltages. The calculated error at a simulated temperature of 1200°C at the portside plastomatic would be -5.2 percent for this meter.

TABLE 2. SUMMARY OF TEMPERATURE MEASUREMENT SYSTEM AUDIT RESULTS

Thermocouple Identity	Average Difference (^{o}C)	Average Difference (%) [a]
Portside Combustion TC		
Camerabox Meter	64[b]	5.5[b]
Combuston Room Meter	39[b]	3.8[b]
Portside Plastomatic TC		
Camerabox Meter	-52	-7.2
Starboard Combustion TC		
Camerabox Meter	59[b]	5.2[b]
Combustion Room Meter	66[b]	5.6[b]
Starboard Plastomatic TC		
Camerabox Meter	+104	+15.7

[a] Values reported are the averages of the percent differences calculated as follows:

$$\frac{\text{Analyzer Response - Audit Value}}{\text{Audit Value}} \times 100 = \text{Percent Difference}$$

[b] The value reported is an absolute value which is comprised of positive and negative data points. See Section 5 for specific data.

2.3 TRW DRY GAS METER AUDIT

TRW utilized two Research Appliance Corporation Method 5 sampling trains to sample emissions from the starboard incinerator. One of the two sampling systems was audited to determine the accuracy of the train's dry gas meter. The audit results are presented in Table 3. Note that preliminary results show the TRW values to be approximately 11 percent lower than the RTI audit values. Examination of the preliminary calculations determined TRW used an incorrect temperature conversion when calculating standard volume as well as applying the meter box correction to the volume equation incorrectly. Recalculation of the data resulted in a 7.6 precent increase in TRW's standard volume.

Audit data was recalculated using 20°C (as opposed to 25°C) as standard temperature and eliminating a water vapor correction from the standard volume equation.

Final results show the TRW dry gas meter reads 3.1 percent lower than the audit meter.

TABLE 3. SUMMARY OF TRW DRY GAS METER AUDIT RESULTS

Parameter	Average Difference		Linear Regression of TRW DGM Volume (Y) on Audit Volume (X); Y = mX + b		
	(CF)	(%)[a]	Slope (m)	Intercept (b)	Corr. Coeff. (r)
Volume (Preliminary)	-.183	-10.7	0.890	0.00	0.9997
Volume (Final)	-.057	- 3.1	0.956	0.02	0.9997

[a] Values reported are the averages of the percent differences calculated as follows:

$$\frac{\text{TRW DGM Volume - Audit Volume}}{\text{Audit Volume}} \times 100 = \text{Percent Difference}$$

SECTION 3

AUDIT PROCEDURES

3.1 CONTINUOUS EMISSION MONITORING SYSTEM

The Vulcanus carried three continuous emission monitors manufactured by Siemans for monitoring carbon monoxide, carbon dioxide and oxygen within each of its two incinerators. A ceramic sample probe protruding from inside each incinerator wall was the point of sample entry into the sample system. The sample gas continued through Teflon lines to a filtering and conditioning system prior to entry into each of the monitors. Audit of the monitors was achieved by supplying known concentrations of one pollutant at a time to the ceramic probe located inside the starboard incinerator. Stable responses were read from each of the monitor's meters.

The RTI audit procedures revealed that there was a significant leak in the starboard sampling system. After numerous attempts to resolve the problem, the leak was located at the probe/sample line junction. The ceramic probe was disassembled, examined, refitted and installed by the ship's crew. Thereafter, supplying audit gases directly to the probe (via a Tygon line fitted snugly inside the probe) produced no leaks. A similar leak check was performed on the port incinerator sampling system without detection of a leak.

Audit gases for the oxygen monitor were supplied directly from compressed gas cylinders. The carbon dioxide and carbon monoxide audit gases were supplied by dynamic dilution of high concentration standards using compressed nitrogen as the diluent. Procedures for establishing traceability of all audit standards are presented in Section 7.

3.2 TEMPERATURE MEASUREMENT SYSTEM AUDIT

Temperatures in the walls of each incinerator are monitored by a system of Platinum/Platinum-10-Rhodium thermocouples with redundant readout meters located in the combustion room and the camerabox. For the purpose of the audit, only the readout meters for the combustion thermocouples and the plastomatic thermocouples were evaluated. The audit was performed by disengaging each thermocouple from the readout meter leads at the interface of the incinerator wall. At this point, leads from an audit battery box (RTI #101) replaced the thermocouple wires, thus allowing a direct connection between the battery box and the readout meter. The output voltage of the battery box was adjustable between 0 and 1000 millivolts and thus could be adjusted to simulate millivolt impulses created by the thermocouples sensing heat. Also connected to the battery box was an NBS referenced voltmeter (Fluke Model 8024A, S/N 2530273) from which the audit millivolt readings were taken. Voltages simulating temperatures of 1400°C, 1200°C, 1100°C and 900°C were delivered to each readout meter. Meter readings were taken simultaneously from the combustion room and the camerabox. Reference temperatures at the junction box were a constant 31°C.

3.3 TRW DATA GAS METER AUDIT

One of the two TRW Method 5 meter boxes was audited to determine the accuracy of the dry gas meter. To audit the TRW meter, an audit dry gas meter was connected to the inlet of the sampling train, which effectively took the place of the sample probe. (See Figure 1.) The audit procedure entailed operating the TRW Method 5 sampling pump at five different flow rates and recording the parameters of temperature and pressures produced by the two devices. Time measurements were also taken from which audit flowrates were subsequently calculated.

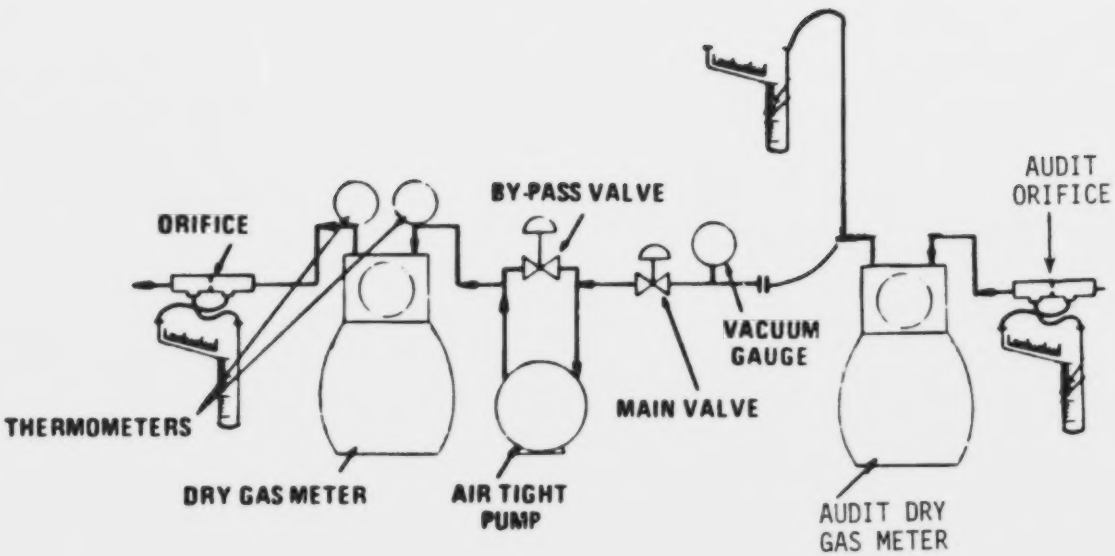

Figure 1. Dry Gas Meter Audit Configuration

SECTION 4

CALCULATIONS

The following formulas were used in the calculation of data presented in this report.

4.1 CONTINUOUS EMISSION MONITOR AUDIT CALCULATIONS

$$\text{Audit Concentration} = \frac{[P] \times Q_p}{Q_p + Q_d}$$

where:

- $[P]$ = Concentration of pollutant in compressed gas cylinder
- Q_p = Flowrate of pollutant gas stream
- Q_d = Flowrate of dilutant gas stream

$$\text{Flowrate} = \frac{V}{\theta} \times \frac{P_b - P_{H_2O}}{P_{std}} \times \frac{T_{std}}{T_m}$$

where:

- V = volume of bubble tower (cc)
- θ = decimal minutes for bubble traverse
- P_b = barometric pressure
- P_{H_2O} = water vapor pressure @ T_m
- P_{std} = standard pressure (760 mm Hg)
- T_{std} = standard temperature (298 K)
- T_m = measured temperature at the bubble film

4.2 TEMPERATURE MEASUREMENT SYSTEM AUDIT

All millivolt to temperature conversions were taken from the Thermocouples Calibration Tables for Platinum versus Platinum-10-Percent Rhodium Thermocouples, Handbook of Chemistry and Physics, 48th Edition. The junction box temperature of 31°C (equates to 0.18 mV) was added to the input voltage prior to conversion to °C.

4.3 TRW DRY GAS METER AUDIT

Original RTI equation:

$$V_{std} = V_m \times Y \left[\frac{P_b - P_{H_2O} - \left(\frac{\Delta H}{13.6} \times 25.4 \right)}{P_{std}} \right] \frac{T_{std}}{T_m}$$

where:

V_m = Volume measured by the audit DGM, (ft^3)
Y = audit dry gas meter correction factor, (1.012)
P_b = barometric pressure, (mmHg)
ΔH = head pressure within the dry gas meter, (in H_2O)
P_{H_2O} = water vapor pressure (mmHg)
P_{std} = standard atmospheric pressure, (760 mmHg)
T_{std} = standard temperature, [298 K (preliminary results), 293 K (final results)]
T_m = gas temperature entering audit meter, (K)

This equation is a version of the Method 5 volume equation 5.1 reported in Appendix A, 40 CFR 60, July 1980; modified for negative pressure in the audit dry gas meter and inclusion of a water vapor correction. This equation was subsequently modified to eliminate the water vapor correction in the final audit data calculations.

Original TRW equation:

$$V_{std} = V_m \times 17.71 \times \left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m} \right)$$

This equation is another version of the Method 5 volume equation in which T_{std}, P_{std}, and the TRW meter box correction factor are reduced to the constant 17.71. This equation was subsequently corrected by moving the meter box correction from the denominator of the constant to the numerator (i.e., 17.647 x 0.9961).

SECTION 5

AUDIT RESULTS

5.1 CONTINUOUS EMISSION MONITORING SYSTEM

5.1.1 Carbon Monoxide Monitor

The carbon monoxide monitor audited was a Siemans Model M52, monitor number 014-81610-A110, serial number M04-54. It was operated on the 0 to 500 ppm range and was last calibrated by the ship's electrician on 8-12-82, the day of the audit. Monitor response to the ship's zero calibration gas was 0.0 units and monitor response to the multigas span cylinder containing 48 ppm CO was 10 units on the monitor's readout meter.

Initial results of the audit indicated monitor readings to be approximately 30 percent less than audit values. Two additional audit cylinders were used to verify the audit results. All three standards verified the monitor to be reading approximately 30 percent low. Results of the three-cylinder audit are presented in Table 4. To further confirm the audit results, cylinder 88-120 was air-shipped back to RTI for immediate re-analysis. Verification resulted in no changes in the reported concentrations of this audit standard.

TABLE 4. CARBON MONOXIDE MONITOR AUDIT RESULTS

Audit Cylinder No.	Audit Matrix	Audit Conc. (ppm)	Monitor Response (units)	Monitor Conc. (ppm)	Difference (ppm)	Difference (%)
M388	N_2	0.0	0.0	0.0		---
LL9940	CO/N_2	382.3	61	292.8	-89.5	-23.4
"	"	212.3	27	129.6	-82.7	-39.0
"	"	39.1	3.5	16.8	-22.3	-57.0
"	"	113.7	16.2	77.8	-35.9	-31.6
"	"	38.5	5.5	26.9	-11.6	-30.1
88-126	"	37.4	5.0	24.5	-12.9	-34.5
88-120	"	50.56	7.0	34.3	-16.3	-32.2
			AVERAGE DIFFERENCE:		-38.7	-35.4

Linear regression of monitor response (Y) on audit concentration (X) yields:

$Y = mX + b$;
slope (m) = 0.750
intercept (b) = -6.6
Corr. Coeff (r) = 0.9938

After concluding the audit, a meeting was held with the RTI auditors; the EPA Project Officer, Merrill Jackson; and Robert Hanisch, the ship's scientific observer, to discuss the audit results. One of the main topics was how to compensate for the apparent misreading of the carbon monoxide analyzer. On first analysis it seemed reasonable to calibrate the carbon monoxide monitor by making it read 35 ppm when sampling the ship's calibration gas containing 48 ppm CO. This decision was based on the CO analyzer's response of 35 ppm to the audit sample containing 50.6 ppm CO. This adjustment, unfortunately, compounded the error, for the adjustment should have been to make the monitor's response to it's calibration gas equal 71 ppm because of the CO_2 interference which was subsequently established. The CO_2 interference in the CO monitor was established after the audit of the CO_2 analyzer. As Table 5 discloses, the CO monitor's response increased during increasing CO_2 audit concentrations. The data clearly shows a CO response of 16.8 ppm to a CO_2 concentration of 14.5%. Since the ship's multigas calibration cylinder contains 15% CO_2 in mixture with 48 ppm CO, one would expect an effective CO concentration of ~63 ppm (48 ppm + ~15 ppm) when calibrating the CO analyzer. (Additional discussion on this monitor's calibration is contained in Section 6.)

TABLE 5. CARBON DIOXIDE INTERFERENCE TO CARBON MONOXIDE MONITOR

CO_2 Audit Concentration (ppm)	CO Monitor Response	
	(units)	(ppm)
0.00	<0	<0
3.87	0	0
6.16	0	0
7.66	0	0
9.99	1.0	4.8
14.50	3.5	16.8

5.1.2 Carbon Dioxide Monitor

The carbon dioxide monitor audited was a Siemans Model M52, monitor number 606-02700-0E134, serial number M03-949. It was operated on the 0 to 20% range and was last calibrated by the ship's electrician on 8-12-82, the day of the audit. Monitor response to the zero calibration gas was 0.0 units and monitor response to the multigas span cylinder containing 15% CO_2 was 81 units on the monitor's read-out meter.

Results of the audit are presented in Table 6 and show agreement between audit concentrations and monitor values to be satisfactory.

TABLE 6. CARBON DIOXIDE MONITOR AUDIT RESULTS

Audit Cylinder No.	Audit Matrix	Audit Conc. (ppm)	Monitor Response (units)	Monitor Conc. (ppm)	Difference (ppm)	(%)
CC14247	CO/N_2	76,000	47.0	87,000	10,400	13.6
"	"	61,600	38.5	71,300	9,700	15.7
"	"	38,700	22.0	40,700	2,000	5.2
"	"	99,900	57.0	105,600	5,700	5.7
"	"	145,000	78.0	148,000	3,000	2.1
M388	N_2	0	<0	0	---	---
			Average Difference:		6,200	8.5

Linear regression of monitor response (Y) on audit concentration (X) yields:

$$Y = mX + b$$

slope (m) = 1.025

intercept (b) = 0.34

Corr. Coeff (r) = 0.9969

5.1.3 Oxygen Monitor

The oxygen monitor audited was a Siemans Model M52 monitor number 007-E4900-B110, serial number M04-478. It was operated on the 0 to 15% range and was last calibrated by the ship's electrician on 8-12-82, the day of the audit. Monitor response to the zero calibration gas was 0.0 units and monitor response to the multigas span cylinder containing 9.78% O_2 was 65 units on the monitor's readout meter.

Results of the audit are presented in Table 7 and show agreement between audit concentrations and monitor values to be satisfactory.

The detection of a leak in the starboard sampling system was made during the audit of the first monitor, the carbon dioxide monitor. An elevated oxygen response was recorded on the oxygen monitor while all monitors were sampling the audit zero gas containing nitrogen only. After numerous hours of trouble shooting, the ceramic probe was disassembled to find a gap between the Teflon sample line and the ceramic probe. Grinding the cap holding the Teflon line thereafter allowed the sample line and probe to overlap and subsequently eliminate the leak in the sampling system.

TABLE 7. OXYGEN MONITOR AUDIT RESULTS

Audit Cylinder No.	Audit Matrix	Audit Conc. (ppm)	Monitor Response (units)	Monitor Conc. (ppm)	Difference (ppm)	Difference (%)
M388	N_2	0	5.0	7,500	---	---
LL9915	O_2/N_2	82,100	52.3	78,700	-3,400	-4.1
LL9654	"	123,500	78.0	117,400	-6,100	-4.9
LL4581	"	52,100	35.0	52,700	600	1.2
FF6128	"	26,300	21.0	31,600	5,300	20.2
				Average Absolute Difference:	3,900	7.6

Linear regression of monitor response (Y) on audit concentration (X) yields:

$Y = mX + b$

slope (m) = 0.883

intercept (b) = 0.74

Corr. Coeff (r) = 0.9997

5.2. TEMPERATURE MEASUREMENT SYSTEM AUDIT

Results of the audit of readout meters for combustion and plastomatic thermocouples located in each incinerator are presented in Table 8. The data shows satisfactory performance of all readout meters except the starboard side plastomatic meter, with the performance of the portside plastomatic approaching the warning level. During the audit, the ship's electrician noted differences between the audit values and the readout meter values at 1200°C and adjusted meter readouts as necessary. Due to limited time, verification of adjustments were not made. Plastomatic meters were not adjusted because they were sealed.

TABLE 8. TEMPERATURE MEASUREMENT SYSTEM AUDIT RESULTS

Thermocouple	Meter	Audit Input[a]		Meter Response	Difference	
		(mv)	(°C)	(°C)	(°C)	(%)
Portside Combustion	Camerabox	14.3	1412	1290	-122	-8.6
		11.0	1137	1120	- 17	-1.5
		8.0	877	950	73	8.3
		11.9	1212	1170	- 43	-3.5
		Average Absolute Diff.			64	5.5
Portside Combustion	Combust. Rm.	14.3	1412	1345	- 67	-5.7
		11.0	1137	1140	3	0.3
		8.0	877	940	63	7.2
		11.9	1212	1190	- 22	-1.8
		Average Absolute Diff.			39	3.8
Portside Plastomatic	Camerabox	6.6	750	680	- 70	-9.3
		4.5	546	500	- 46	-8.4
		7.8	859	770	- 89	-10.4
		2.8	371	350	- 19	-5.1
		12.2	1237	1200	- 37	-3.0
		Average Diff.			-52	-7.2
Starboardside Combustion	Camerabox	14.3	1412	1300	-112	-7.9
		11.9	1212	1180	- 32	-2.6
		11.0	1137	1130	- 7	-0.6
		8.0	877	960	83	9.5
		Average Absolute Diff.			59	5.2
Starboardside Combustion	Combust. Rm.	14.3	1412	1310	-102	-7.2
		11.9	1212	1145	- 67	-5.5
		11.0	1137	1090	- 47	-4.1
		8.0	877	925	48	5.5
		Average Absolute Diff.			66	5.6
Starboardside Plastomatic	Camerabox	3.0	392	460	68	17.3
		5.4	635	725	90	14.2
		3.6	455	520	65	14.3
		2.0	284	350	66	23.2
		12.9	1295	1420	125	9.7
		Average Diff.			104	15.7

[a] The junction box temperature of 31°C (equates to 0.18 mv) must be added to the MV input prior to converting to °C.

5.3 TRW DRY GAS METER AUDIT

The preliminary audit results in Table 9 show a 10.7 percent difference between the TRW meter volumes and audit volumes. Investigation into the differences revealed:

- o TRW converted °F to °R incorrectly by using the relationship °F + 530 = °R
- o TRW applied the meter box correction factor in the denominator of the equation rather than the numerator
- o TRW used 20°C as standard temperature

Recalculations using the correct temperature conversion (°F + 460 = °R) and placement of the meter box correction factor produced a significant increase in TRW meter volumes as reflected in the final results.

In considering the water vapor correction in the audit data, the decision was made to remove it from preliminary audit calculations because during a test run, sample air is dried by silica gel prior to entry into the TRW dry gas meter. After the audit, the assumption was made that the volume error due to atmospheric water vapor was the same in both the TRW and the audit dry gas meters and thus can be ignored. Audit data was also modified to reflect a standard temperature of 20°C (common to wet chemistry) rather than 25°C (common to atmospheric chemistry). Examination of the final results show the TRW dry gas meter average readings were 3.1 percent less than the audit values.

TABLE 9. TRW DRY GAS METER AUDIT RESULTS

	Audit Volume (CF)	TRW Volume (CF)	Difference (CF)	Difference (%)
Preliminary Results	1.90	1.693	-.207	-10.9
	1.91	1.719	-.191	-10.0
	1.91	1.699	-.211	-11.0
	1.91	1.699	-.211	-11.0
	0.96	0.859	-.101	-10.5
		Average Difference	-.184	-10.7
Final Results	1.96	1.883	-.077	- 3.9
	1.96	1.912	-.048	- 2.4
	1.96	1.890	-.070	- 3.6
	1.96	1.891	-.069	- 3.5
	0.98	0.957	-.023	- 2.3
		Average Difference	-.057	- 3.1

SECTION 6

RECOMMENDATIONS

6.1 CONTINUOUS EMISSION MONITORS

The discrepancy in the carbon monoxide audit should be resolved. To achieve this end and increase the accuracy of calibration of the remaining two monitors, the following recommendations are made:

1. Perform maintenance on the carbon monoxide analyzer, if possible, to "filter-out" the positive interference of carbon dioxide. If electronic adjustments are not possible, a chemical CO_2 scrubber such as Ascarite may be necessary for scrubbing sample gases and calibration gases immediately prior to entering the carbon monoxide monitor.

2. Alter the calibration system plumbing so that the calibration gases pass through the scrubbers and dryers exactly the same as do the samples from the incinerators. The old plumbing should still be kept intact so that one can have the option to route calibration gases directly to the monitors or through the scrubbers and dryers. Such a check will verify that the scrubbing system is not altering the sample gas.

3. Activate the monitors at least five days prior to a test burn to allow the detectors and associated electronics to stabilize. Check calibration responses twice a day and log results in an appropriate binder. During a burn, continue to calibrate twice a day, logging in results and time of calibration.

4. Recertify the calibration standard to verify the concentration of carbon monoxide.

6.2 THERMOCOUPLE AUDIT

The audit disclosed discrepancies between meters of the same thermocouple as well as errors in accuracy. To correct these discrepancies, the following recommendations are made:

1. Ensure that all meters of a given thermocouple read similarly, either during an actual burn or during a calibration when a known voltage is passed to the readout meters.

2. Ensure the ship's voltmeter used by the electrician is recertified. During the audit, the ship's voltmeter read input voltages approximately 1 millivolt less than the audit voltmeter. Certification of the audit voltmeter to a National Bureau of Standards traceable voltmeter after the audit verified the meter to be accurate and thus still traceable to NBS standards. No corrections to the audit voltmeter readout are or were necessary.

SECTION 7

AUDIT STANDARDS AND VERIFICATIONS

7.1 COMPRESSED GAS STANDARDS

The four oxygen standards were verified on July 15, 1982 through analysis by a calibrated Teledyne Model 320P Oxygen analyzer. Analyzer serial number 26098 was calibrated on July 15, 1982 using a compressed zero air standard from RTI's Audit Standards Verification Center (ASVC) and a span gas consisting of ambient air. Analysis of each standard and audit cylinder was performed in triplicate, sequentially, in order to eliminate any potential drift in the analyzer. The results of the pre-audit verification are presented in Table 10. No post-audit verification was deemed necessary due to the satisfactory performance of the oxygen monitor audit.

TABLE 10. OXYGEN STANDARDS VERIFICATION

Cylinder No.	Matrix	Verified Concentration (% O_2)
FF6128	O_2/N_2	2.63
LL4581	"	5.21
LL9915	"	8.21
LL9654	"	12.35

The four carbon monoxide standards were verified on March 3, 1982 and June 4, 1982 through analysis by a calibrated Bendix NDIR Model 8501-5C Carbon Monoxide analyzer housed in RTI's ASVC laboratory. Calibration of the analyzer was achieved through dynamic dilution of GMPS standards CC16215, and CC13724. Calibration verification was obtained by NBS-SRM 1678C (CAL4740) and NBS-SRM 2636 (CAL2141). The cylinders were immediately analyzed following this calibration and thus

are traceable to the mentioned NBS standards. The results of the pre-audit verification are presented in Table 11. Due to large differences detected during the carbon monoxide monitor audit, RTI cylinder number 88-120 was air-shipped back to the ASVC laboratory for an immediate post-audit verification. Data obtained within 24 hours of the audit re-verified the cylinder contents.

TABLE 11. CARBON MONOXIDE STANDARDS VERIFICATION

Cylinder No.	Matrix	Verified Concentration (ppm)	Post-Audit Verification (ppm)
88-120	CO/N_2	50.56	50.60
88-126	"	253.24	---
CAL-214	"	495.0	---
LL-9940	"	1009.4	---

The carbon dioxide standard was verified on August 6, 1982 through analysis by a calibrated Byron Model 401 Gas Chromatograph/Flame Ionization Detector. The detector output was integrated by a Spectra-Physics LE1528 integrator. Calibration was achieved using a certified zero gas standard and a calibration gas NBS-SRM 1675B (CAL3759) at 14.34% CO_2/N_2. The standards and audit cylinder were analyzed in triplicate, sequentially, to eliminate any potential drift in the analyzer. Results of the audit cylinder verification showed the CO_2 concentration to be 14.5%. This standard is traceable to NBS-SRM 1675B.

7.2 VOLTMETER

The audit voltmeter (Fluke 8024A Multimeter) was verified after completion of the audit on August 23, 1982. Verification was obtained against National Bureau of Standards through a NBS traceable voltmeter, Fluke Model 731A, serial number 168, Traceability Certificate Number 216868. Results of the verification substantiated the accuracy of the audit voltmeter and that no calibration curve or correction factor need be applied to the voltmeter readout. The verification consisted of

checks at 0, 5, 10, 15, 20, 50, 100, 150 and 195 mv. Analysis of the data pairs by least squares linear regression show the correlation coefficient (r) was 1.0, the slope was 0.9994 and the intercept was 0.0007.

7.3 AUDIT DRY GAS METER

The dry gas meter used to audit the TRW Method 5 dry gas meter was calibrated on August 9, 1982. The audit meter, a 1 ft^3/rev American Meter Company Model 5B-225, serial number 66S7688778, was dynamically calibrated against an EPA maintained Laminar Flow Element (a primary standard), model 50 MW20, serial number R-2194-2. The calibration range was from 0 to 3.8 std ft^3/min. The subsequent correction factor for the audit dry gas meter was 1.012.